Diffractive and nondiffractive components of the multiplicity distribution in pp collisions

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Abstract. Topological cross sections for diffractive and nondiffractive components in pp collisions are deduced on the basis of a dynamical model proposed earlier to explain the multiplicity distribution of charged particles. The model has an important prediction for the angular and momentum distributions of charged particles in diffractive events.

Keywords. pp collisions; topological cross sections; diffractive and nondiffractive components.

Several authors (Koba et al 1972, Harari and Rabinovici 1973, Van Hove 1973, Fiabkowski and Miktinen 1973, Lach and Malamud 1973) have attempted to explain the prong multiplicity distribution of charged particles in pp collisions by different approaches. Surveying these attempts, one finds that the prong multiplicity distribution is rather a gross feature of multiparticle production that can be fitted in many ways and not restrictive enough to lead to definite conclusions regarding the pattern of multiparticle production. However, Dao et al (1973) have recently reported measurements on the topological cross sections of a more restrictive type, which put strong constraints on the dynamical models which could be compatible with these results. In the new measurements, one makes a selection of events in which there is a slow moving proton. Dao et al have given explicitly the values of the topological cross sections for events corresponding to \(|t| < 0.25 \text{ GeV}^2\), where \(t\) is the four momentum transfer between the target and the detected proton. From the histograms presented in their paper, one can also deduce the topological cross sections for events corresponding to \(|t| < 0.125 \text{ GeV}^2\) and \(|t| < 0.5 \text{ GeV}^2\). Further the missing mass squared \(M_x^2\), recoiling from the detected proton, has been obtained as a function of the number \(n_e\) of charged particles for the different \(| t |\) cuts, 0.125, 0.25 and 0.5 GeV².

The topological cross sections \(\sigma_{ne}^d\), corresponding to the events in the cut \(|t| < 0.25 \text{ GeV}^2\), have been identified by Dao et al as the diffractive component and the difference \(\sigma_{ne} - \sigma_{ne}^d \equiv \sigma_{ne}^{n.d}\) as the nondiffractive component, where \(\sigma_{ne}\) is the usual topological cross sections without any \(|t|\) cut. The arbitrariness in the \(|t|\) cut in specifying the diffractive component has been justified by citing that the cross sections do not change much when the \(|t|\) cut is increased from 0.25 to 0.5 GeV².

The importance of the new results, in confronting the predictions of specific dynamical models to a test, has been noted. The nova models (Hwa 1970) which
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predict $\sigma_{nc}^d \sim 1/n_c^2$ are seen to be in disagreement with the date. Further the diffractive dissociation models with isotropic decay distribution and a cut off in the momentum in the nova frame, would predict a peaking in the effective mass plot for all charge topologies. Experimentally no such peaking is seen for $n_c \geq 6$. It has already been noted by Vander Velde (1972) at the Chicago Conference, on the basis of data at 100 and 200 GeV, that only about 25% of $\sigma_d$ and a smaller percentage (if any) of $\sigma_{nc}^d (n_c \geq 6)$ could be attributed to single diffraction dissociation. A nova type of model with anisotropic angular distribution, motivated by simple multiperipheral arguments, has been constructed recently by Kajantie and Ruuskanen (1973). Though the disagreement with the effective mass plots associated with usual nova models may be eliminated, the diffractive multiplicity distribution at 303 GeV given in their paper seem to be in poor agreement with the data, as $\sigma_{nc}^d$ falls too fast as $\exp\{- (n_c - 2)/2\}$. 

Recently Chaudhary et al (1973) have proposed a model to explain the pattern of multiplicity distribution in the entire energy range 5–300 GeV. In this model, the multiplicity distribution is composed of a "specific" mixture of Poisson distributions. The individual components of this mixture would roughly correspond to different $|t|$ cuts. The first component corresponds to the smallest $|t|$ cut but its value cannot be fixed on the basis of the model. If one makes the identification that the first component roughly corresponds to the $|t|$ cut at 0.5 GeV, one can compare the predictions of the model for prong multiplicity distribution for diffractive and non-diffractive components with the experimental data of Dao et al. 

We find that, in spite of the arbitrariness in the $|t|$ cut, the theoretical results for $\sigma_{nc}^d$ and $\sigma_{nc}^{n,d}$ are in reasonable agreement with experiment. The shape of the distribution of $n_c^2 \sigma_{nc}^d$ as predicted by the model, compares well with the experimental curve. Though the effective mass plots cannot be predicted straight away from the model, rough bounds on the missing mass for different charge topologies can be inferred. These bounds are seen to be compatible with experiment. Moreover, one does not expect, on the basis of the present model, sharp peakings in the effective mass plots except for $n_c = 2$ and possibly $n_c = 4$. 

We first briefly outline the model to the extent necessary for the present paper and give relevant theoretical expressions. The results are then compared with the experimental data. Finally we present the dynamical implications of our model of diffraction and some theoretical ideas leading to such a dynamical picture. 

According to the model of Chaudhary et al (1973) there are two groups of particles produced in each collision, which are characterized by different number distributions. One group of particles, called non-leading particles, may be identified with the central component or pionization and their distribution is a Poisson in the number of charged pairs. The other group of particles, referred to as leading particles, arise in the decay of two fast moving (in the cm system) baryon-like excited objects. In the energy range which includes ISR energies, the masses of these excited objects need not exceed a few GeV. The leading particles at any given energy would have a variation between 2 and some maximum value $2R$, where $R$ would be a function of energy. The number distribution of leading charged particles is assumed to be a geometric distribution with $R$ terms. Further